Attorney's Ref. No. P214414

PRELOADED DROP HAMMER FOR DRIVING PILES

RELATED APPLICATIONS

This application claims priority of U.S. Provisional Application Serial No. 60/411,683 filed on September 17, 2002.

TECHNICAL FIELD

The present invention relates to methods and apparatus for inserting elongate members into the earth and, more particularly, to drop hammers that create pile driving forces by lifting and dropping a hammer to apply a driving force to the top of a pile.

BACKGROUND OF THE INVENTION

For certain construction projects, elongate members such as piles, anchor members, caissons, and mandrels for inserting wick drain material must be placed into the earth. It is well-known that such rigid members may often be driven into the earth without prior excavation. The term "piles" will be used herein to refer to the elongate rigid members typically driven into the earth.

One system for driving piles is conventionally referred to as a diesel hammer. A diesel hammer employs a floating ram member that acts both as a ram for driving the pile and as a piston for compressing diesel fuel. Diesel fuel is injected into a combustion chamber below the ram member as the ram member drops. The dropping ram member engages a helmet member that transfers the load of the ram member to the pile to drive the

pile. At the same time, the diesel fuel ignites, forcing the ram member and the helmet member in opposite directions. The helmet member further drives the pile, while the ram member begins a new combustion cycle. Another such system is a drop hammer that repeatedly lifts and drops a hammer onto an upper end of the pile to drive the pile into the earth.

Diesel hammers seem to exhibit fewer problems with tension cracking in concrete piles than similarly configured external combustion hammers. The Applicants have recognized that the combustion chambers of diesel hammers pre-load the system before the hammer impact and that this preloading may explain the reduction of tension cracking in concrete piles associated with diesel hammers.

The need thus exists for improved drop hammers that induce stresses in the pile driven that are similar to the stresses induced by diesel hammers.

SUMMARY OF THE INVENTION

The present invention may be embodied as a drop hammer for driving a pile. The drop hammer of the present invention comprises a housing member and a ram member. The housing member defines a housing chamber. The ram member is supported within the housing chamber for movement relative to the housing member between an upper position and a lower position. When the ram member moves into the lower position, the impact of the ram member drives the pile. When the ram member falls below a preload position between the lower and upper positions, fluid within a preload chamber portion of the housing chamber compresses as the ram member moves into the lower position.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A-1E are somewhat schematic sectional views of a drop hammer of the present invention depicting the drive cycle thereof; and

FIGS. 2-4 represent computer simulations of force records comparing a conventional drop hammer with a conventional diesel hammer under various conditions.

DETAILED DESCRIPTION OF THE INVENTION

Turning to the drawing, depicted at 20 in FIGS. 1A-1E is a drop hammer system constructed in accordance with, and embodying, the principles of the present invention. The drop hammer system 20 is designed to insert a pile 22 into the ground. The drop hammer system 20 will include a spotter, crane, or other equipment as necessary to hold the hammer system 20 in a desired orientation with respect to the ground. Such structural components of the hammer system 20 are conventional and will not be described herein.

The drop hammer system 20 comprises a ram member 30, a helmet member 32, a housing member 34, and a clamp assembly 36. The housing member defines a housing chamber 38. The ram member 30 is guided by the housing member 34 for movement within the housing chamber 38 between a lower position (FIG. 1B) and an upper position (FIG. 1D). The helmet member 32 is guided by the housing member 34 for movement between a rest position (FIG. 1A) and an impact position (FIG. 1B). The helmet member 32 is rigidly connected to the clamp assembly 36. The clamp assembly 36 is detachably fixed relative to the pile 22.

A preload chamber portion 40 is formed within the housing chamber 38 of the housing member 34 between a lower surface 42 of the ram member 30 and an upper surface 44 of the helmet member 32. The ram member 30 further defines an outer surface 46, while the helmet member 32 defines an outer surface 48. First and second seals 50 and 52 are arranged in first and second gaps 54 and 56 between an inner surface 46 of the housing member 34 and the outer surface 46 of the ram member 30 and outer surface 48 of the helmet member 32, respectively. When the seals 50 and 52 function properly, fluid is substantially prevented from

flowing out of the preload chamber portion 40 through the gaps 54 and 56 under certain conditions.

In particular, a vent port 60 is formed in the housing member 34. The vent port 60 is arranged to allow exhaust gasses to be expelled from the preload chamber portion 40 under certain conditions and to allow air to be drawn into the chamber 40 under other conditions. The vent port 60 thus defines a preload position above which fluid can flow into and out of the preload chamber portion 40 and below which the preload chamber portion 40 is substantially sealed.

FIG. 1 illustrates a latch assembly 70 that moved up and down as will generally be described below. The latch assembly 70 represents an external lifting system that lifts the ram member 30 from the lower position to the upper position. The latch assembly 70 mechanically latches onto the ram member 30 during lifting and releases from the ram member 30 when the ram member reaches its upper position. The latch assembly 70 and external lifting system are well-known in the art and will not be described herein in detail.

The drop hammer system 20 operates in a drive cycle that will now be described with reference to FIG. 1. Referring initially to FIG. 1A, the hammer system 20 is shown in a preload state. In the preload state, the ram member 30 has dropped past the vent port 60 such that the first seal 50 prevents fluid from flowing out of the preload chamber portion 40. The second seal 52 seals the opposite end of the preload chamber portion 40 as generally described above. Accordingly, at this point the preload chamber portion 40 is effectively sealed, and continued dropping of the ram member 30 compresses the fluid within the preload chamber portion 40. During this preload state, the helmet 32, the clamp assembly 36, and the pile 22 are gradually forced together by the compressed fluid in the preload chamber portion 40.

Referring now to FIG. 1B, the hammer system 20 is shown in an impact state in which the lower surface 42 of the ram member 30 contacts the upper surface 44 of the helmet member 32. In the impact state, the ram member 30 drives the helmet member 32 towards the pile 22 relative to the housing member 34 as shown by a comparison of FIGS. 1A and 1B. The helmet member 32 thus drives the pile 22 downward through the clamp assembly 36. In addition, the housing member 34 will immediately fall onto the helmet member 32, thereby applying additional driving forces onto the pile member 22.

After impact, the helmet member 32 is raised to an upper position as shown in FIG. 1C. As the helmet member 32 moves into the upper position, the lower end of the ram member 30 passes the vent port 60. As the ram member continues on to its upper position, ambient air is drawn into the preload chamber portion 40 through the vent port 60, thereby reducing resistance to continued upward movement of the helmet member 32. As generally described above, the ram member 32 is raised by the latch assembly 70, which is in turn driven by an external combustion source in a manner similar to that of a conventional drop hammer. In addition or instead, a hydraulic actuator may be used to raise the latch assembly 70 and ram member 32.

After the ram member 30 reaches the upper position as shown in FIG. 1D, the latch assembly 70 releases and the ram member 30 is allowed to drop again. The system 20 then enters a free-fall state as shown in FIG. 1E. In the free-fall state, the preload chamber portion 40 is not sealed, and air is allowed to escape through the vent port 60, again reducing resistance to downward movement of the ram member 32. As the ram member 30 continues to drop, the first seal 50 on the ram member 32 again passes the vent port 60, which seals preload chamber portion 40. Again, the system 20 enters the preload state as described with reference to FIG. 1A. At this point, and the drive cycle begins again.

Given the foregoing general discussion of the invention, certain aspects of the exemplary hammer system 20 will now be described in further detail. The helmet member 32 comprises an inner portion 80 that lies within the preload chamber portion 40, a connecting portion 82 that extends through a helmet opening 84 formed in a bottom wall 86 of the housing member 34, and an outer portion 88 that is connected to the clamp assembly 36. The length of the connecting portion 82 (i.e., the distance between the inner portion 80 and outer portion 88) defines the range of movement of the helmet member 32 between the rest position and the impact position. The second seal 52 is formed on the inner portion 80 of the helmet member 32.

The theoretical benefits of preloading the system by compressing fluid prior to impact will now be described with reference to FIGS. 2-4. FIGS. 2, 3, and 4 plots computer generated models illustrating force versus time for various diesel and drop hammer configurations.

FIG. 2 illustrates the difference between a diesel hammer and a conventional drop hammer. The plot of FIG. 2 assumes the following conditions: 12" square concrete pile 400' in length with a three-inch thick plywood pile cushion; the pile was embedded 20 feet with a total soil resistance of 100 kips. The 400' pile length is not realistic but illustrates wave compression at the upper end of the pile without the effects of reflected waves. Trace 90a corresponds to the force record of an American Piledriving Equipment D-19-32 diesel hammer, while trace 92a corresponds to a conventional drop hammer of similar geometry and weight under the same conditions.

The trace 90a illustrates that the force during the time corresponding to a first time second Aa in FIG. 2 is the pile top force caused by the diesel hammer pre-compression force. In the first time sector Aa, the ram has moved past the exhaust ports and is compressing the air in the combustion chamber and thereby exerting a force on the pile.

Impact occurs at first time point P1a at the end of the first time sector Aa. The impact exerts an impact force during a second time sector Ba between the first point P1a and a second time point P2a. This second sector Ba represents the force at the top of the pile from the time of impact to the time of ram separation. During this second time sector Ba, pile penetration is induced by the large force arising from ram impact. Somewhere around the second time point P2a, the ram has separated from the impact block. A third time sector Ca begins at the second time point P2a; the third time period corresponds to the period from ram separation to the arrival of the reflection of the impact wave back from the toe of the pile. The force during this time comes from the combustion chamber pressure.

The force associated with the conventional drop hammer is shown by the trace 92a. The trace 92a illustrates that the stroke is set such that the same peak impact force was obtained. The double humped force record in sector Ba associated with impact is likely due to the dynamic interaction of the ram, pile cushion, and helmet. While a similar effect is associated with trace 90a in sector Ba, the effects of the dynamic interaction of the ram, pile cushion, and helmet are likely smoothed by the combustion chamber pressure. After the impact as shown at P1a, the drop hammer force stays near zero during the third time sector Ca.

The relatively slow decay of the induced force after the impact event associated with the diesel hammer trace 90a provides a compression force that acts to reduce the magnitude of any reflected tension stresses. The downward traveling compression wave associated with the trace 90a reduces the reflected tension wave from the pile toe.

FIG. 3 illustrates a more realistic example using a conventional diesel hammer system to drive a pile having a length of 100'; all other conditions are also the same. As shown by trace 90b, the element with the largest tension stress was located about 30 feet from the top of the

pile. The maximum tension force at point 3 in FIG. 3 was 106 kips or 736 psi.

FIG. 4 contains a trace 92c of a conventional drop hammer. Illustrated at point 1 on the trace 92c in FIG. 4 is element with the largest tension stress. This element is about 30 feet from the bottom of the pile and represents a maximum tension force of approximately 166 kips or 1,140 psi. The tension force associated with the trace 92c is thus significantly larger than that represented by the trace 90b.

Given the foregoing, the Applicants have concluded that the operation of conventional drop hammer systems can be improved by establishing a pre-load state prior to impact that is generally similar to the compression state of a diesel hammer. The Applicants believe that the preload state will stretch out the compression force in the stress wave and thereby substantially reduce the possibility of tension cracking and damage in concrete piles.